Chapter 1.7
Real-Time Communications in Wireless Sensor Networks

Isabelle Augé-Blum
Université de Lyon, France

Fei Yang
Université de Lyon, France

Thomas Watteyne
Université de Lyon, France

ABSTRACT

This chapter presents the state-of-the-art of real-time communication in the challenging topic of Wireless Sensor Networks (WSNs). In real-time communication, the duration between the event which initiates the sending of a message, and the instant this message is received must be smaller than a known delay. Because topologies are extremely dynamic and not known priori, this type of constraint is very hard to meet in WSNs. In this chapter, the different communication protocols proposed in the literatures, together with their respective advantages and drawbacks, are discussed. We focus on MAC and routing because they are key layers in real-time communication. As most existing protocols are not suitable under realistic constraints where sensor nodes and wireless links are unreliable, we give, at the end of this chapter, some insights about future trends in designing real-time protocols. We hope to give the reader an overview of recent research works in this complex topic which we consider to be essential in critical applications.

INTRODUCTION

Wireless Sensor Networks (WSNs) have experienced a tremendous upsurge in recent years, both in the academy and the industry. These networks are composed of a potentially (very) large number of battery-powered nodes capable of measuring physical parameters, processing them, and communicating wirelessly. Communication is done in a multi-hop ad-hoc manner without requiring a pre-installed fixed infrastructure. Data gathered by the sensors is collected by a sink node which is generally more powerful and less energy-constrained than the low-end sensors nodes. WSNs are foreseen to be used in a wide range of applications, generally classified in five domains: military, environment, health, intelligent

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homes and other commercial solutions (Akyildiz et al., 2002). As an example, a company called Coronis Systems (Dugas, 2005) based in Southern France has deployed a 25,000-node network in Les Sables d'Olonne, France. Each sensor node is attached to a home's water meter and reports daily consumption to the local water provider.

Because of the plethora of applications, new constraints emerge, including timeliness constraints. These emerge from critical application such as a fire detection. Sensor nodes are scattered throughout a forest to monitor temperature. Whenever they sense an abnormal raise in temperature, an alarm message is sent to the sink node, which is directly connected to the fire brigade. In this type of application, the fire brigade needs to be warned within three minutes from the detection of the fire. If the alarm message has not reached the sink node within those three minutes, the surveillance system is considered to have failed. In this case, the impact of the fire on the environment or even on human lives can be dramatic.

Industrial applications with similar constraints exist, and industrial wired network solutions have been successfully rolled out for more than two decades (Rodd et al., 1998). Such networks are embedded in planes, rockets, cars. They are also used for nuclear power plants surveillance or production chain monitoring. Although this technology is ripe, it has never been used outside local and small areas.

WSN applications are different for mainly two reasons: the use of the wireless link, and a deployment over larger area. For an application to cope with timeliness constraints, the underlying communication network protocols need to be real-time. This chapter deals with the new field of real-time communication in the context of WSNs.

BACKGROUND

Applications with timeliness constraints are called "real-time". When an event happens, the application should deal with it within a known and bounded delay. The application taking more time can have a potentially (very) negative impact. Real-time applications are classified in two categories. Hard real-time applications are such that the bounded delay absolutely needs to be met. Examples include forest fire detection. Soft real-time applications are looser in that they can tolerate not to meet a deadline. Examples include multimedia applications. Applications can be classified in four categories, according to how data exchange is initiated. In event-driven application, communication starts when some event happens. In query-driven applications, communication only starts when a specific node sends a query. This specific node can be the sink node in the case of WSNs. In time-triggered applications, communication happens at predefined instants. Finally, some applications such as live video transmission require data to continuously flow through the network. Each one of these application categories has specific time-related constraints.

Distributed real-time applications have emerged in the 1980's, and many solutions exist today. For an application to be real-time, the underlying network must be able to deal with real-time constraints. So far, only local area networks were considered, as they needed to be deployed only over small areas. The size of such an area is typically a building (e.g. nuclear power plant surveillance network) or smaller (network embedded in planes, cars or train). As a result, all communicating parts are connected to the same (wired) network and it is unnecessary to implement the complete OSI stack (Tanenbaum, 2002). Only physical, medium access control (MAC) and application layers are required. In such a simplified setting, the MAC protocol is central, and determines whether the medium access delay is bounded or not. If this delay is deterministic, known and bounded, the system is considered real-time. A "real-time" protocol is not per se "fast". It only means it guarantees the transmission of

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